INDIVIDUAL DIFFERENCES IN SUSCEPTIBILITY TO INATTENTIONAL BLINDNESS

by

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A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Psychology

The University of Utah

August 2010

The University of Utah Graduate School

STATEMENT OF THESIS APPROVAL

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ABSTRACT

Inattentional blindness (IB) refers to the finding that people do not always see what appears in their gaze. Though IB affects large percentages of people, it is unclear why there are individual differences in susceptibility. The present study addressed whether individual differences in attentional control modulate susceptibility to IB. Using an operation span task, participants were sorted into low, medium, or high levels of attentional control. Participants watched a classic IB video and were instructed to count passes among basketball players, wherein 42% failed to notice the unexpected: a person wearing a gorilla suit. When participants were on-task with their pass counts, susceptibility to IB decreased dramatically across the low, medium, and high groups (64%, 48%, and 35%, respectively). These results suggest that variability in attentional control is a potential mechanism underlying the apparent modulation of IB across individuals.

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INTRODUCTION

It has been demonstrated that people do not always see what appears in their line of sight. This observation has been termed inattentional blindness (hereafter, IB; see Mack & Rock, 1998; Neisser & Becklen, 1975; Simons & Chabris, 1999). A typical laboratory task assessing IB requires an individual to perform an attention-demanding task (primary task) during which an unexpected stimulus is presented (e.g., a moving bar, a black diamond, or a gorilla) at one critical trial or time point. The individual will then be asked if they noticed anything unusual or unexpected during their performance of the primary task. Individuals that indicate not seeing anything unusual are said to be exhibiting IB. For example, in a classic experiment, Simons and Chabris (1999) asked participants to watch a video where several actors were playing basketball, and unbeknownst to the participants, another actor in a gorilla suit proceeded to walk across the frame, pause for a moment, beat its chest, and then exit the frame. As the primary task for subjects was to count passes among the actors who were playing the basketball game, the gorilla frequently went unnoticed by participants, typically about 44% of the time. Though large percentages of people have clearly been shown to demonstrate IB, for the purpose of the present study, it is unclear why some individuals are susceptible to IB whereas others are not.

Individual Differences in Susceptibility to Inattentional Blindness

Recently, Simons and Jensen (2009) assessed whether individual differences in ability on the primary task would predict susceptibility to IB. In their study, the participants' primary task was to track multiple objects that were moving at variable speeds. Group status was determined by the speed at which a participant was able to accurately track the objects. Simons and Jensen found that group status on the primary task had no influence on susceptibility to IB. However, despite this null result, other studies in the literature have reported susceptibility to IB that varies across groups. For example, in a basketball/gorilla variant of the IB experiment described above, when actual basketball players were used as participants, they were more likely to notice the unexpected event, quite likely due to their increased expertise or automaticity of the primary task of tracking passes (see Memmert, 2006). Furthermore, Clifasefi et al. (2006) found that intoxicated individuals were more susceptible to IB than their sober counterparts. Finally, it has been argued that individuals with autism may be less susceptible to IB (Grandin & Johnson, 2005). Taken together, these findings suggest that there are individual differences in mental state or cognitive abilities that may underlie differential susceptibility to IB.

An important question remains: Is there a unifying cognitive mechanism that could be used to explain the apparent modulation of IB across individuals? We speculate that individual differences in susceptibility to IB ought to be related somehow to the cognitive construct of attention. For example, it may be the case that intoxicated individuals in the Clifasefi et al. (2006) study were more susceptible to IB due to alcohol's deleterious influence on brain activity in executive attention regions that are housed in frontal cortex (Dao-Castellana et al., 1998). Therefore, we hypothesize that the differential susceptibility that has been observed in the IB literature is due to individual differences in attentional capacity. Consistent with this assertion, older adults are generally more susceptible to IB than young adults (see Rizzo et al., 2009, on aging/change blindness), which may be due, at least in part, to age-related breakdowns in attentional capacity or the control over the contents of their limited capacity attentional resources (see Balota, Dolan, & Duchek, 2000; Watson, Lambert, Miller, & Strayer, in press).

Individual Differences in Working Memory Capacity
And Controlled Attention

Relevant to the present theoretical discussion on attention is the argument that one of the primary functions of working memory is attentional control (Kane & Engle, 2002). Specifically, working memory or executive attention is used to maintain task goals in an active state in the presence of interfering information. From an attentional-control perspective, one might expect individual differences in working memory capacity (hereafter, WMC) to influence performance in cognitively challenging tasks that require the active maintenance of task goals in the face of potentially interfering information (Engle, 2002). Consistent with this reasoning, individuals with lower WMC perform more poorly than individuals with higher WMC in situations where successful performance is dependent on minimizing interference, including but not limited to dichotic listening, the antisaccade task, Stroop color naming, and associative false memory paradigms (see Conway, Cowan, & Bunting, 2001; Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2003; Watson, Bunting, Poole, & Conway, 2005, respectively). For example, using the Stroop task where the participants' goal is to name ink colors and to ignore distracting words, Kane and Engle

(2003) found that individuals with lower WMC produced more naming errors than those with higher WMC in the incongruent condition, and thus were more likely to be off-task and to mistakenly say "red" to the stimulus *RED* printed in green ink.

Earlier we speculated on the role of attentional capacity in modulating susceptibility to IB. More specifically, it may be that individual differences in WMC will predict differential susceptibility to IB. There are some important methodological and theoretical similarities between research on WMC and research on IB that guide this prediction. For instance, consider that in both the IB and WMC literatures, participants are often asked to maintain a primary task goal (e.g., count passes vs. name ink colors, respectively) while a potential source of interference is also presented (e.g., a gorilla vs. a word, respectively). Consistent with this idea, individual differences in WMC have been shown to predict an auditory form of IB more commonly referred to as the *cocktail party effect*. The cocktail party effect is the observation that, when in a noisy environment such as a party, people have the ability to attend to their own conversation and to ignore potentially distracting conversations/stimuli that are occurring around them (with the exception of a salient stimulus like one's own name, which, for some, seems to capture attention fairly automatically). Using a variant of a dichotic listening paradigm developed by Cherry (1953) and Moray (1959), Conway et al. (2001) asked participants to shadow stimuli in one ear and to ignore stimuli in their other ear, where each participant's name was unexpectedly presented in the unattended or to-be-ignored channel. As expected on the basis of the cocktail party effect literature, when questioned after completion of the task, about 40% of the participants did report hearing their name during the experiment. However, Conway et al. also found that there were clear individual differences in susceptibility to the classic cocktail party phenomenon. That is, while 65% of the individuals with lower WMC reported hearing their name, only 20% of the individuals with higher WMC noticed his/her name. According to Conway et al., individuals with higher WMC are more capable of inhibiting non-goal related or distracting stimuli, even if it is as salient and emotionally relevant as one's own name.

Motivation for the Current Study and Predictions

Thus, while there is preliminary support for the idea that individual differences in attentional capacity will modulate susceptibility to IB, the present study sought to provide a strong test of this hypothesis by investigating the relationship between WMC and IB in a large sample (N > 300) of young adults. We believe there are two alternative predictions regarding the direction of the relationship between individual differences in WMC and susceptibility to IB. Interestingly, Conway and colleagues (2001) suggested two similar predictions for individual differences in susceptibility to the cocktail party effect. Given the Conway et al. finding of decreased susceptibility to the cocktail party effect with higher WMC, one would predict a positive relationship between WMC and IB. That is, if failing to notice a salient stimulus like one's own name generalizes to the "gorilla in the room" in a typical IB experiment, individuals with greater WMC will be *more* susceptible to IB. According to this prediction, those with greater WMC are better able to inhibit potentially distracting stimuli, including the gorilla used in classic IB paradigms (Simons & Chabris, 1999). However, this prediction overlooks an important methodological difference between the work of Conway et al. and prevailing IB paradigms. Specifically, in the cocktail party effect study, participants were explicitly instructed to both attend to stimuli in one ear and to ignore stimuli in their other ear. In contrast, in a typical IB study, participants are given a single task goal (e.g., count passes among the actors playing a basketball game), and hence, any additional goal(s) related to unexpected stimuli are ambiguous. Therefore, an alternative prediction is that individuals with greater WMC will be *less* susceptible to IB. According to this prediction, those with greater WMC have more attentional resources at their disposal, and these resources can be used flexibly (e.g., to actively inhibit potential distractions as in the Conway et al. study, or to distribute more broadly across multiple goals). If this is the case, individuals with greater WMC will be better able to maintain a primary goal in an IB study (e.g., counting passes), and they will also have enough residual attentional resources to spontaneously monitor the environment for any unexpected stimuli (e.g., a gorilla). Individuals with lower WMC will have just enough attentional resources to maintain the primary goal but little else, and thus be more susceptible to IB.

METHOD

Participants

Participants included 306 undergraduates enrolled in psychology courses at the University of Utah. They participated in this study in exchange for research credits. All participants were fluent in English based on self-report and were between the ages of 18 and 35.

Design and Materials

Participants were sorted into three groups of subjects with high, medium, or low working memory capacity, respectively, based on their performance on an operation span test (Engle, 2002; Hutchison, 2007). Within the context of the Simons and Chabris (1999) experiment, the primary dependent measure was susceptibility to inattentional blindness (e.g., failing to notice the gorilla in the basketball video that was described briefly in the Introduction). Additional details about tasks and materials are provided below.

<u>Operation span test</u>. Each participant completed an automated operation span test (OSPAN) to obtain a measure of working memory capacity/controlled attention (Unsworth, Heitz, Schrock, & Engle, 2005). In this task, participants were required to solve math problems followed by a to-be-remembered letter – for example, "*Is (8/4) + 3 = 4? A*." After varying numbers of these equation-letter pairs, participants were prompted to recall all of the letters of each set in order. Trials were pseudo-randomized such that participants were

unable to predict the set size of upcoming equation-letter pairs (set size ranged from 3 to 7 equation-letter pairs). Participants were given points equal to the set size when all of the letters in that set were recalled correctly in serial order (i.e., an absolute span score). Total operation span was defined as the sum of points across all of the individual recall periods, with a maximum possible score of 75 points. Math accuracy was also tracked, and feedback was provided to participants during the task. This feedback was intended to keep problem solving accuracy above 85% and to encourage participants' compliance with the dual-task math/memory instructions of the OSPAN task that should place a burden on their limited capacity attentional resources.

Inattentional blindness task. Each participant watched the basketball/gorilla video originally used by Simons and Chabris (1999) to empirically demonstrate the psychological phenomenon of IB. Specifically, participants viewed video footage, lasting about 24 seconds, of six individuals playing a game of basketball. These six individuals were divided into two different teams as designated by the color of their shirts (e.g., black or white). Each team passed a basketball among its three players, making two different types of passes, bounce and aerial. About halfway through the video, unbeknownst to subjects, an actor in a gorilla suit entered from the right view of the shot, proceeded to walk across the frame, paused for a moment in the middle of the frame just in front of the basketball game to beat its chest, and then exited from the left view of the shot (appearing for a total of about 8 seconds). Prior to watching the video, participants were instructed to keep a separate count of both the total number of bounce and the total number of aerial passes made by the black team. To assess susceptibility to IB, at the conclusion of the video, participants were asked for the two pass counts, and if they noticed anything unusual in the video (e.g., a gorilla).

Rather than assuming that participants are actively engaged in counting passes, it is important to consider the actual ability of participants to successfully comply with this primary task goal. Similar to the OSPAN task, compliance with the IB task instructions can be quantified using an accuracy percentage. Participants were considered on-task if their overall accuracy was 80% or above.[1]

Procedure

Following informed consent, participants were tested individually or in groups that ranged from 2 to 5 people while completing the OSPAN test. After a short break, each participant completed the IB task during a one-on-one session with the experimenter. At the conclusion of the experiment, participants received a questionnaire that probed their knowledge of any of the tasks, particularly the IB paradigm, administered in the study.[2]

Endnotes

[1] Accuracy = | (correct bounce pass count – participant's bounce pass count)| + | (correct aerial pass count – participant's aerial pass count)|. This two-step formula involving absolute values takes into account the fact that participants were asked to maintain two separate pass counts – bounce and aerial. To achieve the 80% accuracy criterion that reflected on-task performance, a summed accuracy score of ≤ 4 was required. However, this score could be achieved in a variety of ways [e.g., $4 = |(8-6)| + |(12-14)|$ or $4 = |(8-4)| + |(12-12)|$]. The correct pass counts (i.e., 8 bounce and 12 aerial passes, respectively) were determined by examining still shots of each frame in the single action sequence of the IB/gorilla video from Simons and Chabris (1999).

[2] Participants were removed from analyses reported in the text due to computer/experimenter error (N=10) or for failing to maintain high accuracy (i.e., $\geq 80\%$) on the math portion of the OSPAN task (N=9). As is typically done with IB paradigms (cf., Simons & Chabris, 1999), several participants (N=90) also had to be removed from our analyses due to self-reported knowledge of the IB task. IB, often in conjunction with the gorilla video, is a lecture topic in many of the undergraduate psychology courses that contribute volunteers to the human subject pool at Utah. Overall, this non-naïve group showed less susceptibility to IB (20%).

After applying these three exclusionary criteria, all of the remaining participants (N=197) were included in the final analyses reported in the Results.

RESULTS

The overall probability of IB replicated the findings of Simons and Chabris (1999) with naïve participants showing 42% inattentional blindness. To address potential individual differences in susceptibility to IB, participants were sorted into three groups according to their absolute OSPAN score.[3] As shown in Table 1 and consistent with the broader WMC literature indicating individual differences in goal maintenance, participants with higher OSPAN scores were more likely to be on-task with respect to maintaining accurate pass counts, $F(2,194)=3.81$, $MSe=.24$, $p<05$. Separate chi-square linear-by-linear association tests were then used to detect a potential relationship between OSPAN group and susceptibility to IB for both the on-task and off-task participants. This approach is optimal for showing a linear trend, either positive or negative in direction, with an ordinal variable such as OSPAN group (see Agresti, 1996). When participants were on-task with their pass counts, there was a significant linear-by-linear association between OSPAN group and the probability of IB, $\chi^2(1)=4.88$, $p<.05$. More specifically, as shown in the top panel of Figure 1, susceptibility to IB clearly *decreased* across the low, medium, and high OSPAN groups (64%, 48%, and 35%, respectively). However, as shown in the bottom panel of Figure 1, when participants were off-task with their pass counts, a different pattern of IB emerged across the three OSPAN groups. That is, there was no relationship between OSPAN group and the probability of IB, as low (37%), medium (39%), and high (35%) OSPAN groups were now statistically equivalent in their susceptibility to IB, $\chi^2(1)=.01$, $p=.94$. Finally, consistent with the outcome of these two chi-square analyses, regression analyses showed a significant correlation between the absolute OSPAN score and susceptibility to IB for participants who were on-task with respect to their pass counts (r=.23, p<.05), but no correlation for those participants who were off-task (r=-.06, p=.55). For on-task participants, as the OSPAN score increased, so did the likelihood of noticing the gorilla.

Endnotes

[3] To better represent the distribution of possible scores, participants were sorted on the basis of their absolute OSPAN performance prior to the removal of the non-naïve subjects as described in Footnote 2. In general, the summary statistics on the absolute OSPAN measure for our participants (Mean = 40.39, SD = 17.91, skewness = -.24, and kurtosis = -.68) compared favorably to those originally reported by Unsworth et al. (2005) with the automated OSPAN test. For the participants (N=197) who were included in the final analyses reported in the Results, the mean absolute OSPAN scores for the low (N=63), medium (N=60), and high groups (N=74) were 19, 41, and 59, respectively. Finally, when the absolute OSPAN scores were considered separately for both the on-task and off-task participants (see Table 1), these three group means did not change.

Table 1

Probability and Frequency (N) of On- and Off-Task Pass Counts

as a Function of Performance on the Operation Span Task

Operation Span	Low	Medium	High
On-Task	.35(22)	.45(27)	.58(43)
Off-Task	.65(41)	.55(33)	.42(31)

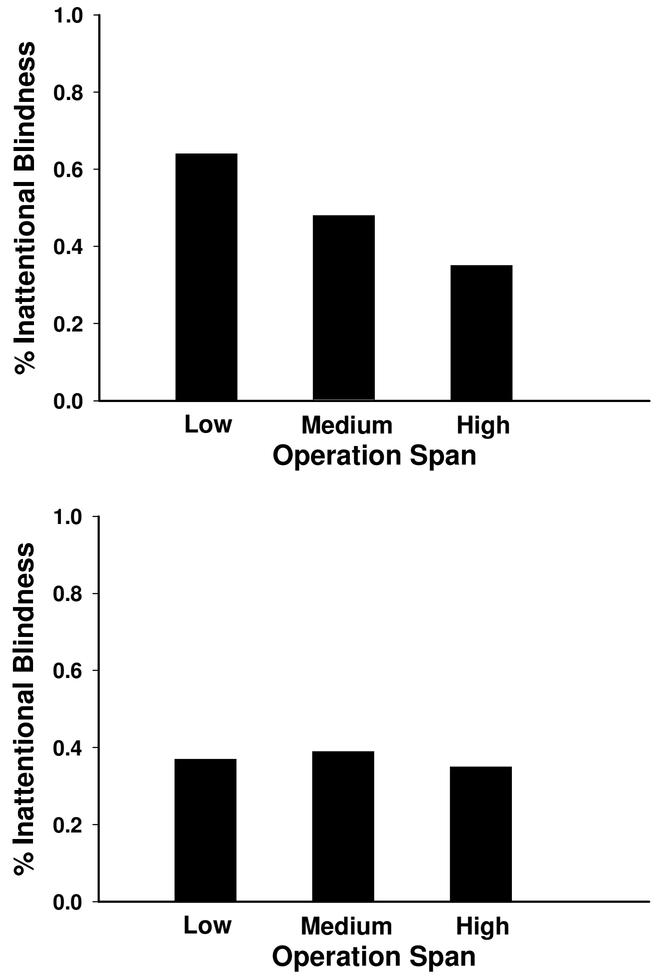

Figure 1

Percent Inattentional Blindness as a Function of Performance

on the Operation Span Task

As shown in the top panel, for those participants who were on-task with respect to their pass counts, susceptibility to inattentional blindness decreased with increased working memory capacity. However, as shown in the bottom panel, for those participants who were off-task with respect to their pass counts, there was no relationship between susceptibility to inattentional blindness and individual differences in working memory capacity.

DISCUSSION

There are two important points to note about the results of the present study. First, our results replicated the original Simons and Chabris (1999) experiment with regard to the overall probability of IB. Second, and more importantly, we demonstrated that individual differences in WMC/OSPAN performance modulated susceptibility to IB. Specifically, when participants were on-task with regard to their pass counts, those with lower WMC were more likely to exhibit IB than those with higher WMC. In this way, our IB results are consistent with a growing body of literature on WMC indicating that performance on many "gold standard" cognitive psychology paradigms – including Stroop color naming, the cocktail party phenomenon, or associative memory illusions – is dependent on individual differences in attentional control (Engle, 2002; Watson et al., 2005).

Theoretical Implications of Individual Differences in Susceptibility to Inattentional Blindness

First, consider the potential implication of our IB results for theories of controlled attention and individual differences in frontally-mediated WMC (cf., Kane & Engle, 2002; Watson et al., in press). To place our IB results in an appropriate context, it is noteworthy that the WMC literature contains several examples of studies where individuals with greater WMC are better able than those with lower WMC at simultaneously maintaining two explicitly stated task goals. For instance, individuals with greater WMC are better at simultaneously memorizing letters or words while solving math problems as in an OSPAN task (or comparable complex span tasks; see Conway et al., 2005). As noted earlier, individuals with greater WMC, as measured by varying levels of OSPAN performance, are also better at attending to ink colors while actively inhibiting words as in the classic Stroop task (Kane & Engle, 2003). Taken together, these findings support the notion that the increased attentional resources afforded by greater WMC can be used in a highly flexible manner (e.g., to distribute more broadly across multiple task goals as in math/memory with OSPAN, or to attend to relevant aspects of a stimulus while ignoring potentially distracting dimensions as in ink colors and words, respectively, with Stroop). Returning to the present study, our IB results extend this notion of more flexible thought with greater attentional resources in an important way. Specifically, recall that in our IB study participants were only instructed to count passes; hence, any additional task goals were ambiguous. In other words, in contrast to the OSPAN and Stroop tasks, participants were not explicitly told to either attend to or to ignore possible distractions. Yet, as shown in the top panel of Figure 1, individuals with greater WMC were more likely to *spontaneously* allocate their additional attentional resources to detect any unusual stimuli that appeared, including the gorilla, thereby decreasing susceptibility to IB. Though flexible processing has long been considered a hallmark of higher-order cognition (Fuster, 1985), within the executive attention literature (see Engle, 2002; Kane & Engle, 2002; 2003), it is atypical to report individuals with greater WMC exerting more attentional control than those with lower WMC in the *absence* of explicit, experimenter-provided task goals (see Watson et al., 2005, for additional discussion). But our WMC/IB results are more generally consistent with the finding of increased cognitive flexibility and response to novel, unexpected stimuli with greater frontally-mediated executive attention resources (Fougnie & Marois, 2007; Kiehl et al., 2001; Knight, 1991).

With respect to implications for designing studies that investigate individual differences in susceptibility to IB, our results suggest that there are two important methodological points to consider. First, one's ability to observe possible individual differences in susceptibility to IB is predicated upon establishing that participants are compliant with primary task goals. Put differently, as shown in the bottom panel of Figure 1, we did not observe a relationship between individual differences in WMC and susceptibility to IB when participants were off-task with respect to the goal of counting passes. Second, though being on-task with a primary goal is necessary for observing individual differences in susceptibility to IB, in and of itself, it is clearly not sufficient. One must also characterize individual differences in terms of limited capacity attentional resources (Engle, 2002), or more specifically, variability in participants' ability to successfully maintain task goals (e.g., counting passes) in the face of potentially interfering information (e.g., a gorilla). Consistent with this argument, in a recently published IB study, Simons and Jensen (2009) used a multiple object tracking task and investigated the relationship between individual differences in tracking speed and susceptibility to IB. Prior to assessing IB, variability in tracking speed was determined adaptively for each participant to achieve a uniform 75% accuracy threshold, thereby assuring that all participants were on-task. Interestingly, individual differences in this processing speed measure did not modulate susceptibility to IB. In contrast, Hannon and Richards (2010) used a very similar multiple object tracking task to Simons and Jensen (2009) and reported that individual differences in WMC, as indexed by OSPAN performance, did modulate susceptibility to IB. More specifically, Hannon and Richards found that individuals who noticed the unexpected stimuli in their object tracking task had slightly higher OSPAN scores than those who failed to notice the unexpected stimuli (also see Richards, Hannon, & Derakshan, in press). In other words, presence/absence of IB was the independent variable for sorting participants, and OSPAN scores were the dependent variable (i.e., the opposite of the approach illustrated in Figure 1). They also obtained a significant correlation between susceptibility to IB and OSPAN performance, where individuals with greater WMC were less susceptible to IB (virtually identical to the correlation reported in our Results).

Why do individual differences in WMC predict susceptibility to IB, whereas variability in object tracking speed does not? One possible explanation for the discrepancy between the results of Hannon and Richards (2010) and those of Simons and Jensen (2009) stems from the observation that measures of WMC and processing speed, though somewhat correlated, appear to capture relatively distinct aspects of cognition (cf., McCabe et al., 2010). For our purposes, the central point is that WMC measures like OSPAN are an especially sensitive measure of individual differences in controlled cognition or management of distraction, and are driven, at least in part, by limited capacity executive attention resources in prefrontal cortex (Kane & Engle, 2002; Watson et al., in press). Hence, to the extent one is on-task with a primary goal in an IB study, individual differences in WMC may be an ideal proxy for quantifying the residual executive attention resources that are available for noticing unexpected stimuli and, by extension, for predicting one's level of susceptibility to IB. In this light, the results of our study resolve an emerging discrepancy in the attention literature and suggest that there indeed are individual differences in cognitive abilities that underlie differential susceptibility to IB. Furthermore, as is traditionally done within the

WMC literature, our participants were sorted into varying levels of attentional control to address a particular research question. That is, in contrast to Hannon and Richards, OSPAN performance was the independent variable, and susceptibility to IB was the dependent variable. As nicely illustrated in Figure 1, the primary advantage of this approach is that it facilitates estimates of the relative susceptibility to IB across different levels of WMC, allowing one to cautiously ascribe a causal role to individual differences in attentional control (akin to Conway et al., 2001, who quantified differential susceptibility to the classic cocktail party phenomenon for those with high and low WMC; see Engle, 2002, for additional discussion). Moreover, our study demonstrated decreased susceptibility to IB with increasing WMC in a classic IB paradigm, where IB was assessed using the gorilla video from the original Simons and Chabris (1999) study rather than more recently implemented multiple object tracking tasks (cf., Hannon & Richards; Simons & Jensen).

Conclusions and Future Directions

In conclusion, the results of the present study demonstrated that individual differences in WMC modulated susceptibility to IB, resolving a discrepancy between the results of Simons and Jensen (2009) and those more recently reported by Hannon and Richards (2010). Specifically, when participants were on-task with regard to their pass counts, those with lower WMC were more likely to exhibit IB than those with higher WMC. In this way, our results are more broadly consistent with other recent studies suggesting that diminished attentional control increases the likelihood of missing unexpected events (see Rizzo et al., 2009, for evidence of increased change blindness in older adults and in patients with Alzheimer's disease). Future studies addressing potential individual differences in susceptibility to IB may find it useful to directly compare the predictive ability of WMC with other cognitive measures (e.g., processing speed, personality profiles) within the same participants. Alternatively, were one to disambiguate task goals with respect to unexpected stimuli (e.g., the gorilla), the direction of the relationship between individual differences in WMC and susceptibility to IB might reverse. That is, in contrast to our findings shown in the top panel of Figure 1, were participants explicitly instructed to *inhibit* the critical IB stimulus, individuals with greater WMC might now be *more* susceptible to IB. Such a finding would be more consistent with the results of the Conway et al. (2001) cocktail party study, and our alternative hypothesis, where as many as 80% of individuals with high WMC failed to notice their own name in the unattended channel. At present, our results clearly suggest that considering WMC, or variability in attentional control, is an effective mechanism to explain the apparent modulation of IB across individuals.

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